

Noise spectroscopy of optical microcavity

G. G. Kozlov

e-mail: gkozlov@photonics.phys.spbu.ru

Institute of Physics, Saint-Petersburg State University, Spin Optics Laboratory, Saint-Petersburg, 198504, Russia

Abstract

The intensity noise spectrum of the light passed through an optical microcavity is calculated with allowance for thermal fluctuations of its thickness. The spectrum thus obtained reveals a peak at the frequency of acoustic mode localized inside the microcavity and depends on the size of the illuminated area. The estimates of the noise magnitude show that it can be detected using the up-to-date noise spectroscopy technique.

1 Introduction

The recent progress in the area of digital high-speed spectrum analyzers of electric signals gave rise to a strong increase of the interest to the optical noise spectroscopy [1, 2, 3, 4, 5, 6]. In the first experimental observation of EPR of sodium atoms in the Faraday rotation noise spectrum [7], a high polarimetric sensitivity [8] made it possible to detect the above spectrum using a conventional lock-in amplifier. Application of the up-to-date digital Fourier analyzers with accumulating systems of data acquisition allowed one to detect magnetic resonance spectra in a number of solid-state objects [3] and to widen the spectral range of the noise signal detection up to several GHz. In this note, we describe the effect of the noise modulation of intensity of quasi-monochromatic light passed through an optical microcavity. The modulation arises due to thermal fluctuations of thickness (and, hence, of the resonance frequency) of the microcavity.

In accordance with the calculations presented in this work, experimental observation of this effect proves to be possible with the aid of the digital spectrum analyzer mentioned above. In this paper, we primarily consider possibility of detection of this effect and only briefly discuss its informative potentialities.

Let us clarify in more detail the idea of the proposed effect. Consider an optical cavity (Fabry-Perot interferometer) - two mirrors separated by a gap L . When the reflectivity of the mirrors is close to unity, the frequency dependence of the transmission coefficient I/I_0 of such a cavity in the vicinity of the principal mode can be written in the form

$$\frac{I}{I_0} = \frac{\Delta^2}{\Delta^2 + (\omega - \omega_0)^2} \quad (1)$$

Here, $I_0(I)$ is the intensity of the monochromatic plane wave with the frequency ω at the entrance (at the exit) of the interferometer and $\omega_0 = \pi c/L$ is the resonance frequency of the interferometer (c is the speed of light in the medium between the mirrors). The width of the transmission spectrum of the interferometer Δ is determined by the reflectivities of the mirrors and, for real microcavities, the finesse $Q \equiv \omega_0/\Delta$ can reach 1000. A change in the cavity thickness $L \rightarrow L + \xi$ gives rise to a change in its resonance frequency $\omega_0 \rightarrow \omega_0 + \delta\omega_0$, which, at $\xi/L \ll 1$, is described by the relationship $|\delta\omega_0/\omega_0| = |\xi/L|$. Bearing this in mind, one can easily make sure, using (1), that the relative change of the cavity thickness $|\xi/L| \sim 1/Q$, results in changes of its transmission coefficient of about unity and can be easily detected. In this case, the absolute changes of the cavity thickness ξ , for typical values of parameters of the optical microcavities, $L = 0.25\mu\text{m}$, $Q = 1000$, are of the order of atomic dimensions $\xi \sim 0.25$ nm. So high sensitivity of transmission of the optical cavity to variations of its parameters is used in physical experiments [9] and allows one to set a question about possibility to detect the cavity transmission noise related to the cavity thickness thermal fluctuations. To evaluate possibility of observation of this noise, its magnitude should be compared with that of the shot noise of the used light source. Corresponding calculations are presented in the next section.

2 Model calculations

Consider an optical cavity formed by a thin layer of a medium, with the thickness L , sandwiched between two thin reflecting films. Let a monochromatic light beam with the intensity I_0 and frequency ω be incident on this cavity. Denote the area of the light spot on the cavity as D^2

and the cavity finesse as Q .¹ The coordinate system is chosen so that the plane of the cavity coincides with the xy plane. Then, the cavity thickness will be a function of x and y , which can be presented as a sum of the constant mean thickness L and small thermal fluctuation $\xi(t, x, y)$. We assume that the resonance frequency of the cavity is determined by its thickness averaged over the area D^2 of the light spot.² Now, the fluctuation δI of the transmitted light intensity can be written as

$$\delta I = G(\omega) \int_{D^2} dx dy \xi(t, x, y), \quad \text{where } G(\omega) = \frac{I_0}{D^2} \frac{d}{d\omega_0} \left(\frac{\Delta^2}{\Delta^2 + (\omega - \omega_0)^2} \right) \frac{d\omega_0}{d\xi} \Big|_{\xi=0}, \quad \omega_0 = \frac{\pi c}{L + \xi}. \quad (2)$$

The greatest value of the factor G is attained at $\omega = \omega_0 - \Delta$: $G(\omega_0 + \Delta) = I_0 Q / 2LD^2$. We will be interested in the intensity noise spectrum $S(\nu)$ of the light transmitted by the cavity. The function $S(\nu)$ is connected with the correlation function $\langle \delta I(0) \delta I(t) \rangle$ by the relationship:

$$S(\nu) = \int dt e^{i\nu t} \langle \delta I(0) \delta I(t) \rangle \quad (3)$$

Using (2), we obtain for $\langle \delta I(0) \delta I(t) \rangle$ the following expression:

$$\langle \delta I(0) \delta I(t) \rangle = G^2(\omega) \int_{D^2} \int_{D^2} dx dy dx' dy' \langle \xi(0, x, y) \xi(t, x', y') \rangle \quad (4)$$

To calculate the correlation function $\langle \xi(0, x, y) \xi(t, x', y') \rangle$ entering Eq.(4) we have to:

- (i) specify a model of motion of the material of the cavity,
- (ii) obtain the appropriate Hamiltonian, and
- (iii) fulfill averaging in Eq.(4) with the thermodynamically equilibrium distribution function $\sim \exp[-H/kT]$.

We will describe dynamics of the cavity material in terms of small acoustic waves. We assume that the cavity occupies the region $z \in [0, L]$, $x \in [0, a]$, and $y \in [0, b]$. Since the optical transmission spectrum depends on the cavity thickness along the z -axis, we will be interested only in z -projection of displacement of the cavity material. According to the adopted model, this displacement is described by the acoustic field $u(x, y, z)$ satisfying the wave equation

$$\frac{\partial^2 u}{\partial t^2} = v^2 \Delta u, \quad (5)$$

¹The finesse measured by the half-width of the transmission spectrum may depend on the transverse beam size D , but, at normal incidence, this dependence is weak

²In other words, this is the frequency at which the transmission coefficient of the cavity is the greatest.

Where v – is the velocity of longitudinal sound in the cavity material. The energy of the acoustic field $u(x, y, z)$ is given by the formula

$$E = \int dx dy dz \left\{ \frac{\rho \dot{u}^2}{2} + \frac{\gamma}{2} \left[\left(\frac{\partial u}{\partial x} \right)^2 + \left(\frac{\partial u}{\partial y} \right)^2 + \left(\frac{\partial u}{\partial z} \right)^2 \right] \right\} \quad (6)$$

Here, ρ – is the density of the cavity material and γ – is the constant that described the elastic strain energy density. Connection of this constant with the velocity of sound v will be given below. The direct substitution shows that expansion of solution of Eq. (5) in terms of normal modes, satisfying the boundary conditions

$$\left. \frac{\partial u}{\partial x} \right|_{x=0,a} = 0, \quad \left. \frac{\partial u}{\partial y} \right|_{y=0,b} = 0, \quad \left. \frac{\partial u}{\partial z} \right|_{z=0,L} = 0, \quad (7)$$

which correspond to zero strains at the bounds of the cavity, has the form:

$$u(t, x, y, z) = \sum_{pmn} u_{pmn} \cos\left(\frac{\pi p x}{a}\right) \cos\left(\frac{\pi m y}{b}\right) \cos\left(\frac{\pi n z}{L}\right), \quad p, n, m \text{ integers } p, m, n > 0 \quad (8)$$

where *the degrees of freedom* of the acoustic field u_{pmn} meet the following equations of motion

$$\ddot{u}_{pmn} = -\omega_{pmn}^2 u_{pmn}, \quad \text{where } \omega_{pmn}^2 = v^2 \left[\left(\frac{\pi p}{a} \right)^2 + \left(\frac{\pi m}{b} \right)^2 + \left(\frac{\pi n}{L} \right)^2 \right] \quad (9)$$

Using Eq.(8), we can express the energy E (6) through the degrees of freedom u_{pmn} :

$$\begin{aligned} E &= \frac{V}{16} \sum_{pmn} \left[\rho \dot{u}_{pmn}^2 + \gamma u_{pmn}^2 \left[\left(\frac{\pi p}{a} \right)^2 + \left(\frac{\pi m}{b} \right)^2 + \left(\frac{\pi n}{L} \right)^2 \right] \right] = \\ &= \frac{V}{16} \sum_{pmn} \left[\rho \dot{u}_{pmn}^2 + \frac{\gamma \omega_{pmn}^2}{v^2} u_{pmn}^2 \right] \end{aligned} \quad (10)$$

To obtain the Hamiltonian corresponding to energy (10) , we have to introduce the generalized momenta p_{pmn} , conjugated with the generalized coordinates u_{pmn} so that the equations of motion (9) acquire the form of the Hamilton equations:

$$\frac{\partial H}{\partial u_{pmn}} = -\dot{p}_{pmn} \quad \frac{\partial H}{\partial p_{pmn}} = \dot{u}_{pmn} \quad (11)$$

If we set

$$p_{pmn} \equiv \frac{\dot{u}_{pmn} \rho V}{8} \quad \text{and} \quad \gamma = \rho v^2,$$

and express energy (10) through p_{pmn} and u_{pmn} :

$$H = \sum_{pmn} \left[\frac{4p_{pmn}^2}{M} + \frac{M \omega_{pmn}^2 u_{pmn}^2}{16} \right] \quad M \equiv \rho V \text{ – resonator mass, } p_{pmn} = \frac{M}{8} \dot{u}_{pmn}, \quad (12)$$

then we can easily make sure that equations of motion (9) are equivalent to Eq. (11). Thus, Eq.(12) is the sought Hamiltonian.

Using Hamiltonian (12), we can write the following expression for the distribution function $\sigma\{p_{pmn}, u_{pmn}\}$ of the generalized coordinates and momenta in the state of thermodynamic equilibrium with the inverse temperature $\beta = 1/kT$:

$$\sigma\{p_{pmn}, u_{pmn}\} = Z^{-1} \exp \left[-\beta H\{p_{pmn}, u_{pmn}\} \right] \quad (13)$$

where Z is the normalizing constant. Now, if we express, using Eq. (8), the changes of the cavity thickness $\xi(t, x, y)$ through the degrees of freedom u_{pmn}

$$\xi(t, x, y) = u(t, x, y, 0) - u(t, x, y, L) = 2 \sum_{pmn} u_{pm,2n-1} \cos\left(\frac{\pi p x}{a}\right) \cos\left(\frac{\pi m y}{b}\right), \quad p, m, n > 0, \quad (14)$$

then, for the correlation function entering Eq. (4), we obtain the expression

$$\begin{aligned} & \langle \xi(0, x, y) \xi(t, x', y') \rangle = \\ & = 4 \sum_{pmn} \sum_{p'm'n'} \langle u_{pm,2n-1}(0) u_{p'm',2n'-1}(t) \rangle \cos\left(\frac{\pi p x}{a}\right) \cos\left(\frac{\pi m y}{b}\right) \cos\left(\frac{\pi p' x'}{a}\right) \cos\left(\frac{\pi m' y'}{b}\right) \end{aligned} \quad (15)$$

Since the distribution function is factorized over the degrees of freedom u_{pmn} (i.e., the degrees of freedom are independent random quantities with zero mean value), the off-diagonal mean values in the double sum of Eq. (15) vanish, and we have

$$\begin{aligned} & \langle \xi(0, x, y) \xi(t, x', y') \rangle = \\ & = 4 \sum_{pmn} \langle u_{pm,2n-1}(0) u_{pm,2n-1}(t) \rangle \cos\left(\frac{\pi p x}{a}\right) \cos\left(\frac{\pi m y}{b}\right) \cos\left(\frac{\pi p x'}{a}\right) \cos\left(\frac{\pi m y'}{b}\right) \end{aligned} \quad (16)$$

Let us calculate the correlator of the type $\langle u(0)u(t) \rangle$ (the subscripts are omitted for brevity). Since the degrees of freedom meet the equation of motion $\ddot{u} = -\omega^2 u$, we can write the following expression for $u(t)$:

$$u(t) = u(0) \cos[\omega t] + \frac{\dot{u}(0)}{\omega} \sin[\omega t] \Rightarrow \langle u(0)u(t) \rangle = \langle u^2(0) \rangle \cos[\omega t] + \langle u(0)\dot{u}(0) \rangle \frac{\sin[\omega t]}{\omega} \quad (17)$$

The velocity $\dot{u}(0)$ entering the last term of Eq. (17) is proportional to the corresponding generalized momentum, which is a random quantity independent of u . Therefore, $\langle u(0)\dot{u}(0) \rangle = 0$, and we have:

$$\langle u(0)u(t) \rangle = \langle u^2(0) \rangle \cos[\omega t] \quad (18)$$

It follows from Eqs. (12) and (13) that, if we introduce notation $\alpha \equiv M\omega^2/16kT$, then

$$\langle u^2(0) \rangle = \sqrt{\frac{\alpha}{\pi}} \int u^2 \exp[-\alpha u^2] du = -\sqrt{\frac{\alpha}{\pi}} \frac{\partial}{\partial \alpha} \int \exp[-\alpha u^2] du = \frac{1}{2\alpha} = \frac{8kT}{M\omega^2} \quad (19)$$

Thus, using Eq.(16), we obtain

$$\langle \xi(0, x, y) \xi(t, x', y') \rangle = \frac{32kT}{M} \sum_{pmn} \frac{\cos[\omega_{pm,2n-1}t]}{\omega_{pm,2n-1}^2} \cos\left(\frac{\pi px}{a}\right) \cos\left(\frac{\pi my}{b}\right) \cos\left(\frac{\pi px'}{a}\right) \cos\left(\frac{\pi my'}{b}\right) \quad (20)$$

Now, let us take into account that the dimensions a and b are supposed to be large, i.e., $a, b \gg L$. In this case, we can pass from summation over p and m to integration. By denoting $[\pi p/a] \equiv A$ and $[\pi m/b] \equiv B$, we obtain

$$\omega_{pmn} \rightarrow \omega_n(A, B) = v \sqrt{A^2 + B^2 + \left(\frac{\pi n}{L}\right)^2}, \quad dA = [\pi/a], \quad dB = [\pi/b]$$

and

$$\langle \xi(0, x, y) \xi(t, x', y') \rangle = \frac{32kT}{M} \frac{ab}{\pi^2} \sum_n \int_0^\infty dA dB \frac{\cos[\omega_{2n-1}(A, B)t]}{\omega_{2n-1}^2(A, B)} \cos(Ax) \cos(By) \cos(Ax') \cos(By') \quad (21)$$

Since Eq. (4) includes the correlation function (21) averaged over the area of the light spot, it is convenient to introduce the function $F(A, B)$ defined as

$$F(A, B) \equiv \int_{D^2} dx dy \cos[Ax] \cos[By] \quad (22)$$

Then, taking into account that

$$\int \cos[\Omega t] e^{i\nu t} dt = \pi [\delta(\nu - \Omega) + \delta(\nu + \Omega)],$$

and using Eqs. (3), (21), and (22), we obtain for the sought spectral density of the noise $S(\nu)$ the following equation

$$S(\nu) = G^2(\omega) \frac{32kT}{M} \frac{ab}{\pi} \sum_n^{\text{odd}} \int_0^\infty dA dB \frac{\delta[\nu - \omega_n(A, B)]}{\nu^2} F^2(A, B) \quad (23)$$

Here, the symbol *odd* shows that summation is performed over odd n . Using the presence of δ -function, we can perform integration over B , and eventually we have

$$S(\nu) = \frac{G^2(\omega)}{\nu} \frac{32kT}{L\rho\pi v^2} \sum_n^{\text{odd}} \int dA \left[\left(\frac{\nu}{v}\right)^2 - A^2 - \left(\frac{\pi n}{L}\right)^2 \right]^{-1/2} F^2\left(A, \sqrt{\left(\frac{\nu}{v}\right)^2 - A^2 - \left(\frac{\pi n}{L}\right)^2}\right) \quad (24)$$

Here $\rho \equiv M/abL$ is the density of the cavity material, and the integration is performed over the range of values of the variable A , where the radical entering Eq. (24) is real. The

contribution of the n -th mode is evidently nonzero only at $\nu > [\pi n v / L]$. As was already mentioned, the greatest value of $G(\omega)$ is achieved when the interferometer is tuned to the slope of the resonance:

$$G_{max} = G(\omega_0 + \Delta) = \frac{I_0 Q}{2LD^2}.$$

In this case, the noise intensity is the greatest and equals

$$S(\nu) = \frac{(I_0 Q)^2}{\nu L^3 D^4} \frac{8kT}{\rho \pi v^2} \sum_n^{odd} \int dA \left[\left(\frac{\nu}{v} \right)^2 - A^2 - \left(\frac{\pi n}{L} \right)^2 \right]^{-1/2} F^2 \left(A, \sqrt{\left(\frac{\nu}{v} \right)^2 - A^2 - \left(\frac{\pi n}{L} \right)^2} \right) \quad (25)$$

To make quantitative estimates, we assume, for simplicity, that the light beam has a square cross section, i.e., $x \in [a/2 - D/2, a/2 + D/2]$ and $y \in [b/2 - D/2, b/2 + D/2]$. In this case, the function $F(A, B)$ (22) can be obtained in the explicit form:

$$F(A, B) = \frac{4}{AB} \cos \left(\frac{Aa}{2} \right) \sin \left(\frac{AD}{2} \right) \cos \left(\frac{Bb}{2} \right) \sin \left(\frac{BD}{2} \right)$$

Note that the rapidly oscillating terms (of the type $\cos^2[Bb/2]$) arising in the formula for $F^2(A, B)$ can be replaced by their mean values (i.e., by $1/2$). With allowance for these remarks, we may accept that

$$F^2(A, B) = \frac{1}{A^2 B^2} \sin^2 \left(\frac{AD}{2} \right) \sin^2 \left(\frac{BD}{2} \right) \quad (26)$$

All the above calculations refer to infinite phonon lifetime in the cavity material. This is the reason why the correlation function (18) does not decay. If we take into account the decay of the acoustic mode free vibrations and temporal evenness of the correlation function, we obtain, for the correlator, the following expression:

$$\langle u(0)u(t) \rangle = \langle u^2(0) \rangle \cos[\omega t] \exp - \left| \frac{t}{\tau} \right| \quad (27)$$

where τ – is the phonon lifetime. The noise spectrum $S_\tau(\nu)$, in this case, is obtained as a convolution of Eq.(25) and Lorentzian with the width³ equal to the inverse phonon lifetime τ^{-1} :

$$S_\tau(\nu) = \frac{\tau}{\pi} \int \frac{S(\nu' - \nu)}{1 + [\nu' \tau]^2} d\nu' \quad (28)$$

3 Possibility of observation of the microcavity noise

One of the most popular optical microcavities is the Bragg cavity, namely, the Fabry-Perot interferometer comprised of two Bragg mirrors separated by a half-wave gap. In spite of the fact

³As we will see below, the noise spectrum appears to be localized in a rather narrow spectral region, where the frequency dependence of τ may be neglected

that these microcavities represent multi-layer structures, the intensity noise of the transmitted light can be estimated using Eqs. (25) and (28) for the following reason. It is essential for the single-layer model considered above that both the optical and the acoustic modes are localized in the *same layer* of the material which may serve as a resonator both for the optical and for the acoustic waves. A similar situation may take place in real Bragg cavities, since the optical Bragg mirror also has an acoustic stop-band and can efficiently reflect acoustic waves with the appropriate frequencies. In this case, the half-wave gap (for optical waves) between the Bragg mirrors can form an acoustic resonator, whose properties can be approximately described by the single-layer model described in the previous section. Our quantitative estimates show that, for a typical half-wave Bragg cavity with $\lambda_0 = 2\pi c/\omega_0 = 800$ nm, comprised of the TiO_2 and SiO_2 layers, the frequency of the lowest acoustic mode equals 10 GHz and matches the acoustic stop-band of the Bragg mirrors. The possibility of manufacturing of efficient acoustic Bragg resonators was demonstrated in [10, 11, 12, 13].

Bearing in mind all the aforesaid, let us accept the following values of the parameters entering Eqs. (25) and (28): $L = 0.276$ μm , $I_0 = 0.1$ W, $Q = 1000$, $v = 5570$ m/s (SiO_2), $\rho = 2000$ kg/m³ (SiO_2). For the above values of the parameters, the frequency ν_1 of the lowest acoustic mode ($n = 1$) can be estimated as $\nu_1 = v/2L \approx 10$ GHz. As seen from Eqs. (25) and (28), the noise power increases with decreasing size of the light spot D . In our calculation, we accept that $D = 10$ μm . This size of the spot does not contradict the above finesse $Q = 1000$.⁴ To estimate the decay time τ of acoustic vibrations, entering Eq. (28), we can take into account that the finesse of the quartz resonators at frequencies of around 10^8 Hz may reach $10^4 - 10^5$. For the frequencies $\sim 10^{10}$ Hz, we are interested in, the finesse of the acoustic vibrations is expected to be lower. Thus, for our estimates, we will accept the finesse of the acoustic mode to be ~ 2000 . In this case, the quantity τ is determined by the relationship $\nu_1\tau = 2000$. The possibility of manufacturing of acoustic microcavities with a finesse of around 1000 in the THz range was reported in [14].

To estimate possibility of observation of the intensity noise of the light transmitted by the microcavity, the magnitude of this noise (determined by Eqs (25) and (28)) should be compared with the shot noise of the light source

$$S_{sn} = I_0 \hbar \omega_0 \quad (29)$$

⁴Further decrease of D by light focusing can be accompanied by a decrease of the finesse, which occurs due to increasing uncertainty in the angle of incidence. However, for normal incidence of the focused beam, this effect is not strong.

The results of this comparison are shown in Fig. 1. This figure shows the calculated noise spectra in the region of the lowest acoustic mode ($n = 1$) for the infinite (oscillating curve) and finite (smooth curve) phonon lifetime. Horizontal line shows the level of shot noise of the used light Eq. (29). Since observation of the light shot noise with the aid of the up-to-date spectrum analyzers does not encounter any problems, then, as seen from Fig. 1, we have all the grounds to believe that the above effect can be detected even if the results of our calculations appear to be overestimated by 1-2 orders of magnitude. ⁵

4 Conclusions

In this paper, we presented calculations of spectral power density of the light transmitted by a microcavity. It is shown that this power density reveals a peak at the frequency of acoustic vibrations of the cavity – the effect similar to Raman scattering. The quantitative estimates are made which show that the noise arising due to the mechanism considered in the paper can be detected using the up-to-date noise-spectroscopy technique.

Without entering into details of possible informative capabilities of this technic, note only that thermal vibrations are usually considered as a spurious factor that restricts operational stability of devices (see, i.g.,[15]. The above calculations show, however, that the intensity noise spectrum of the light transmitted by the cavity contains information about the spectrum of acoustic vibrations of the structure. Measuring variation of this spectrum versus the light spot diameter will allow one to judge about plausibility of the used simple model which neglects, in particular, disorder of the real structure and possible localization of the acoustic waves. Observation of the correlation function of the noise for two spaced light beams will possibly allow one to evaluate the localization radius of acoustic vibrations of the structure.

5 Acknowledgements

The author is grateful to V.G.Davydov for useful discussions.

⁵Spectral region of the modern digital spectrum analyzers is restricted to the frequencies of around 1-2 GHz. For this reason, for detection of the noise signal with the frequencies ~ 10 GHz, considered in this paper, one has to perform the appropriate transfer of the spectrum. A similar task is solved in the systems of satellite TV with the aid of heterodyne converters, which can also be used in this case.

References

- [1] T. Yabuzaki, T. Mitsui, and U. Tanaka, Phys. Rev. Lett., v.67, n.18, p.2453,(1990).
- [2] Mitsui, T., 2000, Phys.Rev. Lett. 84, 5292
- [3] Crooker, S. A., D. G. Rickel, A. V. Balatsky, and D. Smith, 2004, Nature 431, 49.
- [4] McIntyre, D. H., C. E. Fairchild, J. Cooper, and F. Walser, 1993, Opt. Lett. 18, 1816
- [5] R. Walser, P.Zoller, Phys.Rev. A, v. 49, n.6, p.5067, (1993).
- [6] Müller, G. M., M. Oestreich, M. Römer, and J. Hubner, 2010b, Physica E 43, 569
- [7] Aleksandrov, E. B., and V. S. Zapasskii, 1981, JETP 54, 6412.
- [8] Aleksandrov E.B., and V.S. Zapasskii, Optika I Spektroskopiya v. 41, Issue: 5 p. 855-858 (1976).
- [9] Juejun Hu, OPTICS EXPRESS, Vol. 18, No. 21, 22174, (2010).
- [10] N. D. Lanzillotti-Kimura, A. Fainstein, A. Lemaitre, B. Jusserand, and B. Perrin, Phys.Rev. B 84, 115453 (2011).
- [11] M. F. Pascual Winter, G. Rozas, A. Fainstein, B. Jusserand, B. Perrin, A. Huynh, P. O. Vaccaro, and S. Saravanan, Phys.Rev.Lett. 98, 265501 (2007).
- [12] N. D. Lanzillotti-Kimura, A. Fainstein, B. Perrin, and B. Jusserand, Phys.Rev. B 84, 064307 (2011).
- [13] M. Trigo, A. Bruchhausen, A. Fainstein, B. Jusserand, and V. Thierry-Mieg, Phys.Rev.Lett. VOLUME 89, NUMBER 22, (2002).
- [14] G. Rozas, M. F. Pascual Winter, B. Jusserand, A. Fainstein, B. Perrin, E. Semenova, and A. Lemaître, Phys.Rev.Lett. 102, 015502 (2009).
- [15] T.S.Jaseja, A.Javan, and C.H. Townes, Phys.Rev. Lett. 10, n. 5, p.165, (1963).

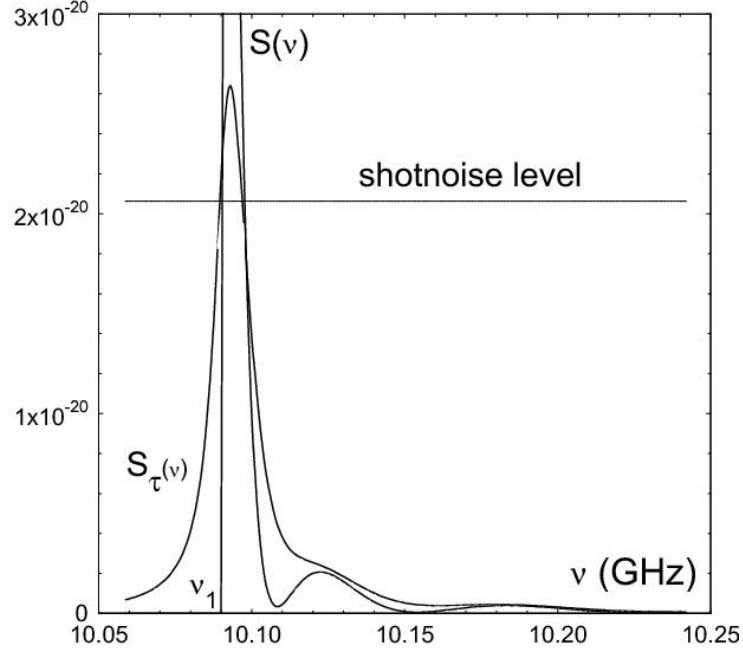


Figure 1: The intensity noise spectrum of the light transmitted by the cavity. The values of the parameters are: thickness of the microcavity $L = 0.276 \mu\text{m}$, finesse of the transmission spectrum $Q = 1000$, and the light beam intensity $I_0 = 0.1 \text{ W}$. The calculation is performed for the spectral region of the lowest acoustic mode of the cavity $\nu_0 \approx 10 \text{ GHz}$. Oscillating curve $S(\nu)$ corresponds to the noise spectrum at infinite phonon lifetime. Smooth curve $S_\tau(\nu)$ – the same at $2\pi\nu_0\tau = 2000$. Horizontal line shows the shot noise level of the light.